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Adiabatic Calorimetry of Lithium Ion Cells
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Incorporating Lithium-Ion batteries into flight systems requires a thermal analysis to insure the desired operating temperature is maintained. One of the inputs to this analysis is the heat rate of the battery cells. The adiabatic calorimetery method gives direct measurements of heat rate. It also has good resolution in the time domain. The changes in temperature were used to calculate the heat rates, thermal efficiency, and thermo-neutral potentials.

The test cells are spiral-wound D-Cells. Wilson Greatbach, Inc fabricated them using the JPL low temperature electrolyte, cobalt oxide cathodes, and MCMB anodes. Two cells were operated in series inside the calorimeter.

The cells were rated at 3.8 ampere-hours. Using the nominal capacity, four rates for both charge and discharge were selected, C/10, C/5, C/3.3, and C/2. A charge and discharge at each of these rates were performed with equilibration periods between each phase. The charge phases used voltage limits of 4.1 volts to control overcharge, and terminated each charge when the taper current reached C/50. Discharges were terminated at 3.0 volts per cell.

The leak rate for the calorimeter was determined to be 44.5 milliwatts per degree Celsius. This deviation from ideal adiabatic behavior was used to correct all results.

The specific heat of the test articles was calculated using the heat loss rate and the weight of the test articles. The specific heat of these cells was determined to be 0.0891 calories/gram-degree.

On charge, the thermal efficiencies vary from 99% to 100.5 percent, (Figure One). The values greater than 100% are due to endothermic behavior at the beginning of charge. It is more pronounced at the lower rates. The exothermic behavior on charge peaks at 100 to 200 mw/cell levels depending upon rate. The thermo-neutral potentials calculated for charge were between 3.5 and 4.1 volts, (Figure 3). The taper current effect during charging makes comparisons of different rates somewhat more difficult, as the tapers start at much different points in each case.

On Discharge, the thermal efficiencies were between 101.3% and 92%, (Figure 2). The thermal efficiency decreased monotonically with depth-of-discharge in nearly all cases. The lowest rates showed a significant amount of endothermic character at the beginning of the discharge, while the highest rate shows none. The calculated thermoneutral potentials each show an S-shaped curve. The TNP increases slowly across abroad plateau, and then falls off steeply at low states of charge, forming an S-shaped curve (Figure 4).

This variation in the TNP with rate does not appear to be caused by higher temperatures. Although temperatures increase to as high as 40 Celsius, the peak temperatures were reached only at the end of the discharge period, and the effect on TNP was immediate. Additional testing showed no effect of rate change on TNP.

Figure One: Thermal Efficiency on Charge

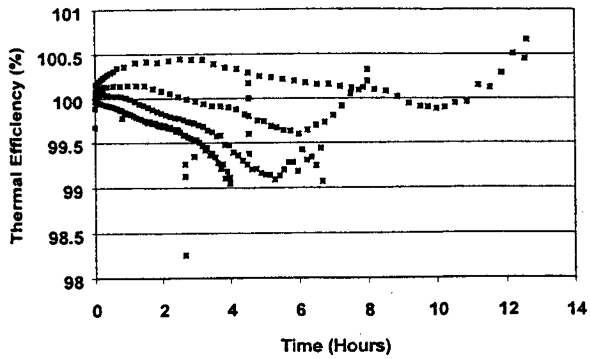

Figure 2: Thermal Efficiency on Discharge

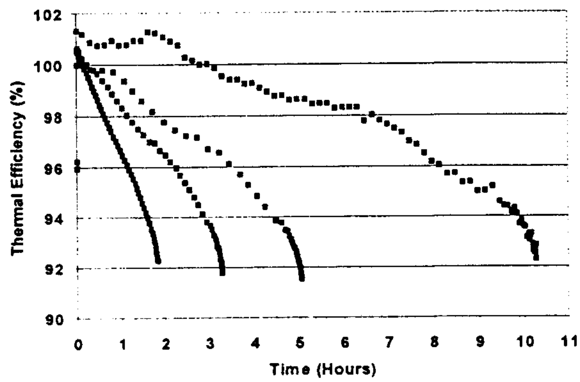

Figure Three:Thermoneutral Potentials on Charge

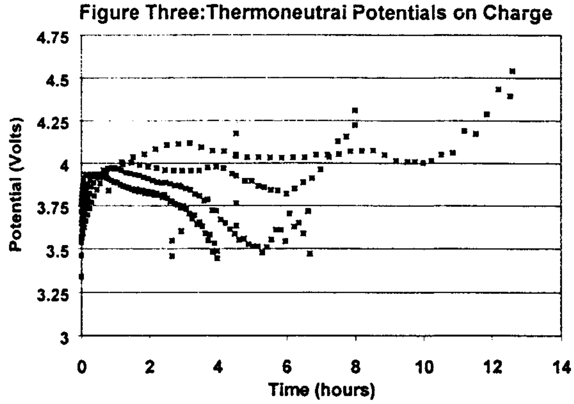

Figure Four: Thermoneutral Potentials on Discharge